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(54) Method of measuring a surface profile using an atomic force microscope

Verfahren zum Vermessen eines Oberflächenprofils mit einem Atomkraftmikroskop

Méthode pour mesurer le profil d'une surface avec un microscope à force atomique

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The present invention relates to a method of measuring a surface profile of a sample using an atomic force microscope which observes a sample surface by making use of interatomic forces acting between a probing tip formed on a free end of a cantilever and the sample surface. Such a method is generally known, for instance from US-A-4 954 704.

The development of atomic force microscopes (hereinafter referred to simply as an AFM) is being advanced, and they are used as an instrument capable of observing the surface of a solid body on an atomic scale.

The principle of an AFM is explained hereinafter with reference to Fig. 5.

In order to detect minute forces, a cantilever 6 having a probing tip 12 and a length ranging from 100µm to 200µm is preferably employed in the AFM. When a sample 21 placed on a sample platform 4 is brought near the probing tip 12, the cantilever 6 deflects in the presence of interatomic forces existing between the probing tip 12 and the sample 21. The AFM scans the surface of the sample 21 by the use of first and second piezoelectric members 1 and 2 and a piezoelectric member drive unit 11 while a third piezoelectric member 3 is being feed-back controlled by the piezoelectric member drive unit 11 via a control signal generator 14 so that the amount of deflection of the cantilever 6 may be maintained constant. The first, second, and third piezoelectric members 1, 2, and 3 are secured to and extend from the sample platform 4 in directions shown by arrows X, Y, and Z, respectively. Because the control quantity in such feed-back control is indicative of height variations of the sample surface, an AFM image is obtained by converting the control quantity into image information using a controller or computer 10. Alternatively, the AFM image can be obtained by converting the amount of deflection of the cantilever 6 into image information without performing the feed-back control. The amount of deflection of the cantilever 6 is detected by a deflection detector 22 wherein the principle of optical beam deflection, laser interference, tunnel current, or the like is utilized. The resolution of the AFM depends upon the radius of curvature of the probing tip 12. The less the radius of curvature is, the higher the resolution is. At present, an atomic image of, for example, mica is observed by a probing tip having a radius of curvature of several hundreds angstroms. The AFM is used to observe not only a sample surface on an atomic scale but also another sample surface having relatively large height variations in unit of nanometers (nm) or micrometers (µm). The observation of the sample surface of the latter, for example a grating having relatively deep grooves, requires a probing tip having a small radius of curvature and a high aspect ratio sufficient to reach bottoms of the grooves. In this respect, a whisker crystal is preferably used as the probing tip.

As a matter of course, in applications where the probing tip 12 is scanned on the surface of the sample 21, the cantilever 6 deflects in the presence of height variations of the sample surface. In addition to such deflection, variations in friction coefficient of the sample surface or a distortion of the cantilever 6 causes a deflection of the cantilever 6. This kind of deflection brings about noises, and hence, accurate measurement of the surface configuration cannot be expected. By way of example, when mica is used as a sample and a repulsive force of 1×10^{-8}N is chosen to act on the cantilever 6, an AFM image obtained from the amount of deflection of the cantilever 6 indicates a generally symmetric atomic image. On the other hand, when a repulsive force of 1×10^{-7}N is chosen to act on the cantilever 6, the AFM image comes to indicate a non-symmetric atomic image.

Furthermore, in applications where measurements are carried out by the use of a probing tip having a high aspect ratio, and if the sample 21 contains very steep height variations or has grooves with generally vertically extending side walls, a side surface of the probing tip 12 occasionally collides against the side walls of the grooves during scanning. Under such conditions, little deflection of the cantilever 6 would occur, and hence, the scanning is continued with the distance between the sample and the probing tip 12 maintained substantially constant. As a result, not only no accurate AFM image can be obtained, but also the probing tip 12 or the cantilever 6 is occasionally damaged.

In addition, if the sample 21 is a living body which cannot be easily anchored on a substrate, the scanning of the probing tip 12 drags the sample 21 on the substrate, thus resulting in inaccurate measurement.

It is already known in atomic force microscopes when measuring a rather rough material surface, to shift a probe at a distance where the probe and the material to be observed are sufficiently far away from each other relative to the roughness of the material surface (US-A-4 902 892). Moreover, EP-A-347 739 shows an atomic force microscope where a probe is also moved away from the surface of the sample to be observed, so that it can then be moved in a plane successively to points of measurement on the sample surface in order to obtain information of the sample without being disturbed by the roughness of the surface.

It is an object of the present invention to provide an improved method for an atomic fore microscope capable of accurately observing the surface of a sample irrespective of the configuration for the type of the sample.

In accordance with the invention a method of measuring a surface profile of a sample using an atomic force microscope is characterised by the steps of:

(a) positioning the probing tip above one location of the sample surface;
(b) moving one of the cantilever and the sample surface towards the other till the cantilever is deflected

in the presence of the interatomic forces;

(c) measuring a height of the sample surface;

(d) imaging said height measured at step (c);

(e) moving said one of the cantilever and the sample surface away from the other by a constant given distance so that the probing tip is spaced apart from the sample surface, said constant given distance being determined in advance so as to be greater than a maximum value of height variations of the sample surface within a range thereof to be measured;

(f) moving said one of the cantilever and the sample surface relative to the other so that the probing tip is positioned above a next adjacent location of the sample surface spaced apart from said one location;

(g) moving one of the cantilever and the sample surface towards the other by said constant given distance;

(h) repeating said steps (c) to (g) at a plurality of succeeding locations of the sample surface so as to image the height variations of the sample surface.

Preferable embodiments are defined in the dependent claims.

Accordingly, the AFM according to the present invention is free from noises which may be caused, in the conventional AFM, by variations in friction coefficient of the sample surface or a distortion of the cantilever. Even if the probing tip has a high aspect ratio and is used to observe a sample having grooves with generally vertically extending side walls, a side surface of the probing tip does not collide against the side walls. Furthermore, even if a living body, which cannot be easily anchored on a substrate, is used as a sample, the sample is not dragged by the probing tip 12 during scanning.

The above and other features of the present invention will become more apparent from the following description of preferred embodiments thereof with reference to the accompanying drawings, throughout which like parts are designated by like reference numerals, and wherein:

Fig. 1 is a schematic diagram of an atomic force microscope according to a first or second embodiment of the present invention;

Fig. 2 is a timing chart of voltages applied to two piezoelectric members extending in different directions;

Fig. 3 is a diagram similar to Fig. 1, but according to a third embodiment of the present invention;

Fig. 4 is a diagram similar to Fig. 1, but according to a fourth embodiment of the present invention; and

Fig. 5 is a schematic diagram of a conventional atomic force microscope (already referred to).

Referring now to the drawings, there is schematically shown in Fig. 1 an AFM according to a first embodiment of the present invention. This AFM comprises a finely movable mechanism in the form of a tripod, a cantilever 6 disposed in the proximity of the finely movable mechanism, and a probing tip 12 secured to or otherwise integrally formed with a free end of the cantilever 6. The finely movable mechanism comprises a sample platform 4 on which a sample 5 is to be placed, and first, second, and third piezoelectric members 1, 2, and 3 secured to and extending from the sample platform 4 in directions shown by arrows X, Y, and Z, respectively.

The sample 5 is scanned horizontally by applying voltages generated by a piezoelectric member drive unit 11 to the first and second piezoelectric member 1 and 2, respectively. The deflection of the cantilever 6 caused by interatomic forces existing between the sample 5 and the probing tip 12 is detected by making use of the principle of optical beam deflection wherein a laser beam emitted from a laser diode 7 having an output of 5mW is initially focused on the cantilever 6 by a lens 8, and a reflected light beam is detected by a two-segment photodiode 9.

A specific control method is explained hereinafter which was used to observe a cleavage surface of mica.

Mica 5 was initially placed, as a sample, on the sample platform 4 such that a central portion of the former might be positioned below the probing tip 12. Prior to measurement of this sample, the AFM was set so that the cantilever 6 might first receive a repulsive force of 1×10^{-7}N.

Fig. 2 is a timing chart indicating how to apply, after the setting, voltages to the first and third piezoelectric members 1 and 3, respectively. After the amount of deflection of the cantilever 6 was detected by the optical beam deflection, a step voltage Vz was applied to the third piezoelectric member 3 to move the sample 5 1nm away from the probing tip 12. The sample 5 was then horizontally moved 2Å by the first piezoelectric member 1 using the piezoelectric member drive unit 11. Thereafter, the voltage applied to the third piezoelectric member 3 was gradually reduced so that the sample 5 might be moved 1nm towards the probing tip 12, and the amount of deflection of the cantilever 6 was stored in a controller or computer 10. Height variation or undulation information at various points of the sample surface was derived from the amount of deflection of the cantilever 6. The time period required for the movement from one point to another was set to 0.2 millisecond, whereas that required for moving the sample 5 away from the probing tip 12 was set to 0.1 millisecond. Such measurements were repeated 256 times in the direction of X until the scanning for one line was terminated. Thereafter, the sample 5 was horizontally moved 2Å by the second piezoelectric member 2, and similar operations were carried out with respect thereto to complete the next succeeding line scanning. Upon completion of 256 line scannings, (256 × 256) pieces of undulation information

were derived from the sample surface. An AFM image obtained from such information indicated an accurate and symmetric atomic image.

The above-described operations of the AFM could reduce the noise level as compared with the conventional case wherein the cantilever continuously scanned the sample surface with a constant repulsive force being applied thereto. Even if measurements were carried out under the influence of a relatively strong repulsive force of 1×10^{-7}N or more, an image obtained indicated a high resolution. One reason for this is deemed to be that a torsional component of the cantilever, which might arise when the sample was scanned in the direction of X, brought about no noises.

In the above-described embodiment, although the measurements required to obtain the undulation information were carried out only once for each point, such measurements may be repeated plural times for each point. It was confirmed that an image obtained by the use of an average value of the repeated measurements included lower noises.

Furthermore, a method employing laser interference or tunnel current can be effectively utilized, as means for measuring the amount of deflection of the cantilever, in place of the method employing the optical beam deflection. It was also confirmed that similar results could be obtained by the use of the former method.

A second embodiment of the present invention is discussed hereinafter wherein an Au film prepared by a sputtering process was observed by the AFM. The construction of the AFM according to the second embodiment is the same as that of the AFM according to the first embodiment discussed above.

A sample 5 having an Au thin film on an Si substrate was initially placed on the sample platform 4 such that a central portion of the sample 5 might be positioned below the probing tip 12. Then, a voltage was gradually applied to the third piezoelectric member 3 by the computer 10 via the piezoelectric member drive unit 11 so that the sample 5 might be brought near the probing tip 12. At this moment, the force acting on the cantilever 6 from the sample 5 was measured by the two-segment photodiode 9. When the cantilever 6 received a repulsive force of a given magnitude, the sample 5 was stopped by the computer 10 from approaching the probing tip 12, and the voltage applied to the third piezoelectric member 3 was stored in the computer 10. Undulation information at each point on the substrate surface was derived from this voltage. In measuring the sample 5, the magnitude of the repulsive force was set to 1×10^{-8}N. Thereafter, the sample 5 was moved away from the probing tip 12 until no force acted on the cantilever 6 from the sample 5. The sample 5 was then moved 2nm leftwards by the first piezoelectric member 1 using the piezoelectric member drive unit 11. Thereafter, a voltage was gradually applied to the third piezoelectric member 3 to make the sample 5 approach the probing tip 12 until the cantilever 6 received a repulsive force of 1×10^{-8}N. The voltage applied to the third piezoelectric member 3 at this moment was stored in the computer 10. Then, the sample 5 was further moved 2nm leftwards by the first piezoelectric member 1. Such measurements were repeated 256 times in the direction of X until the scanning for one line was terminated. Thereafter, the sample 5 was moved 2nm downwards by the second piezoelectric member 2, and similar operations were performed with respect thereto to complete the next succeeding line scanning. Upon completion of 256 line scannings, (256 × 256) pieces of undulation information were obtained from the sample surface.

The above-described operations of the AFM could reduce the noise level and could provide an image having a high resolution, as compared with the conventional case wherein the cantilever continuously scanned the sample surface with a constant repulsive force acting thereon.

Fig. 3 schematically depicts an AFM according to a third embodiment of the present invention.

The amount of deflection of the cantilever 6 was detected by the use of the principle of the optical beam deflection. A zinc oxide whisker 13 which was prepared by vapor deposition was used as a probing tip. Because this whisker has a three-dimensional structure in the form of a tetrapod and has four projections extending from the center of a regular tetrahedron towards respective vertexes, it could be very easily bonded to the cantilever 6 using a bonding material. A grating having a pitch of 1μm and a height of 0.5μm was observed using this cantilever.

A grating 15 was initially placed, as a sample, on the sample platform 4 such that a central portion of the grating 15 might be positioned below the probing tip 13. Prior to measurements of this sample 15, the distance between the sample 15 and the probing tip 13 was controlled so that the magnitude of the repulsive force might become equal to 1×10^{-8}N by the operation of the third piezoelectric member 3 and a control signal generator 14 operatively connected to the photodiode 9. A control voltage applied to the third piezoelectric member 3 at this moment was stored in the computer 10. Undulation information at each point on the substrate surface was derived from this control voltage. Thereafter, a step voltage generated by the computer 10 was added to the control voltage by an adder 16 operatively connected to the control signal generator 14 and to the computer 10. By doing so, the sample 15 was moved 1μm away from the probing tip 13. The sample 15 was then horizontally moved 20nm by the first piezoelectric member 1 using the piezoelectric member drive unit 11. Thereafter, the sample 15 was brought near the probing tip 13 by gradually reducing the voltage added to the control voltage. After the sample 15 was moved 1μm towards the probing tip 13, the control voltage required to generate a repulsive force of 1×10^{-8}N again was stored in the computer 10. During such measurements, the period of time

during which the sample 15 was away from the probing tip 13 was set to 0.1 millisecond, whereas the speed of response of the control signal generator 14 was set to 1 millisecond. Furthermore, the period of time required for the movement between two adjoining points was set to 2 millisecond. Accordingly, no problem arose that the control by the control signal generator 14 followed the movement of the sample 15 away from the probing tip 13. Such measurements were repeated 256 times in the direction of X until the scanning for one line was terminated. Thereafter, the sample 15 was moved 20nm by the second piezoelectric member 2, and similar operations were performed with respect thereto to complete the next succeeding line scanning. Upon completion of 256 line scannings, (256 × 256) pieces of undulation information were obtained from the sample surface.

The use of the conventional AFM employing this cantilever, wherein the sample surface was continuously scanned under the influence of a constant repulsive force, could not provide reliable measurements or sometimes brought about damage of the whisker. The AFM according to the present invention, however, could provide a reliable image having a faithfully reproduced surface configuration, even in bottom configuration of grooves of the sample.

In the above-described embodiment, although explanation was made with respect to the AFM employing the zinc oxide whisker, a whisker crystal of tin oxide, silicon carbide, alumina, a metal, or an organic material such as, for example, phthalocyanine could be used in place thereof. The AFM according to the present invention employing such whisker crystal could provide an AFM image faithful to reproduce the surface configuration of a sample, even if the sample contained grooves having generally vertical side walls.

Fig. 4 schematically depicts an AFM according to a fourth embodiment of the present invention.

The AFM shown in Fig. 4 comprises a finely movable mechanism in the form of a tripod having three piezoelectric members 1, 2, and 3, a fourth piezoelectric member 17 secured to and extending from the finely movable mechanism in a direction opposite to the direction in which the third piezoelectric member 3 extends, and a sample platform 18 placed on the fourth piezoelectric member 17. The fourth piezoelectric member 17 was provided for moving a sample 19 from the probing tip 12.

A specific control method is explained hereinafter which was used to observe flagella of Salmonella bacteria.

A flagella sample 19 was initially placed on the sample platform 18 such that a central portion of the former might be positioned below the probing tip 12. Measurements of this sample were performed in a water pool pipetted so as to be trapped between the sample 19 and a glass plate 20 positioned above the cantilever 6. The distance between the sample 19 and the probing tip 12 was controlled by the control signal generator 14 and the third piezoelectric member 3 so that the repulsive force might become equal to 1×10^{-9}N. The control voltage applied to the third piezoelectric member 3 at this moment was stored in the computer 10. Undulation information at each point on the sample surface was derived from this voltage value. Thereafter, the sample 19 was moved 50nm away from the probing tip 12 by applying a step voltage Vz generated by the computer 10 to the fourth piezoelectric member 17. The sample 19 was then moved 3nm by the first piezoelectric member 1 using the piezoelectric member drive unit 11. Thereafter, the voltage applied to the fourth piezoelectric member 17 was gradually reduced to bring the sample 19 near the probing tip 12. After the sample 19 was moved 50nm towards the probing tip 12, a control voltage required for controlling the repulsive force to become 1×10^{-9}N again was stored in the computer 10. Such measurements were repeated 256 times in the direction of X until the scanning for one line was terminated. Thereafter, the sample 19 was moved 3nm by the second piezoelectric member 2, and similar operations were performed with respect thereto to complete the next succeeding line scanning. Upon completion of 256 line scannings, (256 × 256) pieces of undulation information were obtained from the sample surface. Several flagella each having a diameter of about 20nm and a length of more than 100nm were observed from an AFM image obtained from such information.

According to the AFM as discussed hereinabove, even if flagella which could not be anchored on a substrate were used as a sample, it was recognized that the probing tip did not drag the sample during scanning, and hence, an accurate AFM image could be obtained.

In this embodiment, although the fourth piezoelectric member 17 for moving the sample away from the probing tip was interposed between the sample and the finely movable mechanism, this member 17 could be arranged on the cantilever side. In this case, the resonant frequency thereof was increased, thereby enabling high-speed AFM measurements.

It is to be noted here that, in each of the first to fourth embodiments discussed above, although the sample was moved by the finely movable mechanism in three different directions, the sample may be maintained stationary. In this case, all of the cantilever 6, the laser diode 7, the lens 8, the photodiode 9, and the like should be assembled into one unit so that the unit can be moved by a finely movable mechanism similar to that discussed above or any other suitable means.

It is also to be noted that the amount of movement of one of the sample and the probing tip towards or away from the other is so chosen as to be greater than a maximum value of height variations of the sample surface at least within a range thereof to be measured.

As is clear from the above, the AFM according to the present invention can stably accurately measure extremely small height variations of less than 0.1nm at a reduced noise level. Furthermore, in measuring a grat-

ing having relatively deep grooves or a sample having generally vertically extending side walls, the cantilever or the probing tip is free from damage. Even if a microorganism which cannot be anchored on a substrate is used as a sample, measurements can be carried out with reliability without dragging the living sample by the probing tip. As a result, a highly accurate AFM image can be obtained at a high resolution.

Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted here that various changes and modifications within the scope of the appended claims will be apparent to those skilled in the art.

Claims

1. A method of measuring a surface profile of a sample using an atomic force microscope which observes a sample surface by making use of interatomic forces acting between a probing tip (12) formed on a free end of a cantilever (6) and the sample surface, said method comprising the steps of:

   (a) positioning the probing tip (12) above one location of the sample surface;
   (b) moving one of the cantilever (6) and the sample surface towards the other till the cantilever (6) is deflected in the presence of the interatomic forces;
   (c) measuring a height of the sample surface;
   (d) imaging said height measured at step (c);
   (e) moving said one of the cantilever (6) and the sample surface away from the other by a constant given distance so that the probing tip (12) is spaced apart from the sample surface, said constant given distance being determined in advance so as to be greater than a maximum value of height variations of the sample surface within a range thereof to be measured;
   (f) moving said one of the cantilever (6) and the sample surface relative to the other so that the probing tip (12) is positioned above a next adjacent location of the sample surface spaced apart from said one location;
   (g) moving one of the cantilever (6) and the sample surface towards the other by said constant given distance;
   (h) repeating said steps (c) to (g) at a plurality of succeeding locations of the sample surface so as to image the height variations of the sample surface.

2. The method according to claim 1, wherein the height variations of the sample surface are imaged based on the amount of deflection of the cantilever (6) when one of the cantilever (6) and the sample surface is moved towards each other.

3. The method according to claim 2, wherein said probing tip (12) comprises an acicular projection formed on the free end of the cantilever (6).

4. The method according to claim 3, wherein said acicular projection is a whisker crystal of a material selected from the group consisting of a metal, zinc oxide, tin oxide, alumina, silicon carbide and an organic material.

5. The method according to claim 1, and further comprising, after step (b), the step of controlling the position of said one of the cantilever (6) and the sample surface relative to the other so that the amount of deflection of the cantilever (6) becomes equal to a constant given value, wherein the height variations of the sample surface are imaged based on a control quantity required to render the amount of deflection of the cantilever (6) to be said constant given value.

Patentansprüche

1. Verfahren zum Vermessen eines Oberflächenprofils mit einem Kraftmikroskop unter Ausnutzung der zwischen den Atomen einer Meßspitze (12) und der Oberfläche einer Probe auftretenden Kräfte, wobei die Meßspitze an dem Ende eines freitragenden Hebels (6) angeordnet ist, unter Anwendung folgender Verfahrensschritte:

   (a) Positionieren der Meßspitze (12) oberhalb einer Stelle der Oberfläche der Probe;
   (b) Bewegen des freitragenden Hebels (6) oder der Oberfläche der Probe aufeinander zu, bis der freitragende Hebel (6) durch zwischenatomare Kräfte abgelenkt wird;
   (c) Messen der Höhe der Oberfläche der Probe;
   (d) Anzeigen der während des Schrittes (6) gemessenen Höhe;
   (e) Bewegen des freitragenden Hebels (6) oder der Oberfläche der Probe um einen festen gegebenen Betrag voneinander fort, so daß die Meßspitze (12) sich im Abstand von der Oberfläche der Probe befindet, wobei der feste gegebene Betrag vorher so bestimmt wird, daß er größer als ein Maximalwert der Höhenschwankungen der Oberfläche der Probe ist, in deren Bereich gemessen werden soll;
   (f) Bewegen des freitragenden Hebels (6) oder der Oberfläche der Probe gegeneinander so, daß die Meßspitze (12) sich oberhalb einer nächsten danebenliegenden Stelle der Oberfläche der Probe im Abstand der erstgenannten Stelle befindet;
   (g) Bewegen des freitragenden Hebels (6) und der Oberfläche der Probe aufeinander zu um

den festen gegebenen Betrag;

(h) Wiederholen der Schritte (c) bis (g) an einer Mehrzahl von nachfolgenden Stellen der Oberfläche der Probe, um die Höhenschwankungen der Oberfläche der Probe anzuzeigen.

2. Verfahren nach Anspruch 1, bei dem die Höhenschwankungen der Oberfläche der Probe auf der Basis des Betrages der Ablenkung des freitragenden Hebels (6) beim Aufeinanderzubewegen des freitragenden Hebels (6) und der Oberfläche der Probe angezeigt werden.

3. Verfahren nach Anspruch 2, bei dem die Meßspitze (12) einen nadelförmigen Vorsprung aufweist, der an dem freien Ende des freitragenden Hebels (6) ausgebildet ist.

4. Verfahren nach Anspruch 3, bei dem der nadelförmige Vorsprung ein Whiskerkristall aus einem Material ist, das aus der Gruppe von einem Metall, Zinkoxyd, Zinnoxyd, Aluminiumoxyd, Siliziumkarbid und einem organischen Material ausgewählt ist.

5. Verfahren nach Anspruch 1, bei dem nach dem Schritt (b) die Position des freitragenden Hebels (6) gegenüber der Oberfläche der Probe derart geregelt wird, daß der Betrag der Ablenkung des freitragenden Hebels (6) gleich einem konstanten Wert wird, wobei die Höhenschwankungen der Oberfläche der Probe auf der Basis einer Regelgröße angezeigt werden, die notwendig ist, um den Betrag der Auslenkung des freitragenden Hebels (6) auf dem konstanten Wert zu halten.

Revendications

1. Procédé de mesure du profil d'une surface d'un échantillon en utilisant un microscope à force atomique, lequel observe une surface d'échantillon en utilisant des forces inter-atomiques agissant entre une pointe d'essai (12) formée sur l'extrémité libre d'un élément en porte à faux (6) et la surface d'échantillon, ledit procédé comprenant les étapes :

a) de positionnement de la pointe d'essai (12) au dessus d'un certain endroit de la surface d'échantillon ;

b) de déplacement l'un vers l'autre de l'élément en porte à faux (6) et de la surface d'échantillon jusqu'à ce que l'élément en porte à faux (6) soit dévié en présence des forces inter-atomiques ;

c) de mesure de la hauteur de la surface d'échantillon ;

d) de formation d'une image de la hauteur mesurée à l'étape (c) ;

e) de déplacement, pour les éloigner l'un de l'autre, de l'élément en porte à faux (6) et de la surface d'échantillon d'une distance donnée constante de telle façon que la pointe d'essai (12) est écartée de la surface d'échantillon, ladite distance constante donnée étant déterminée par avance de manière à être supérieure à la valeur maximale des variations de hauteur de la surface d'échantillon dans une plage de celle-ci devant être mesurée ;

f) de déplacement l'un par rapport à l'autre de l'élément en porte à faux (6) et de la surface d'échantillon de telle façon que la pointe d'essai (12) est positionnée au-dessus d'un certain endroit suivant contigu de la surface d'échantillon écartée dudit premier endroit ;

g) de déplacement l'un vers l'autre de l'élément en porte à faux (6) et de la surface d'échantillon ayant ladite distance constante donnée ;

h) de répétition desdites étapes de (c) à (g) une pluralité d'endroits successifs de la surface d'échantillon de manière à former une image des variations de hauteur de la surface d'échantillon.

2. Procédé selon la revendication 1, dans lequel les variations de hauteur de la surface d'échantillon sont formées en image sur la base de l'amplitude de la déviation de l'élément en porte à faux (6) lorsque soit l'élément en porte à faux (6) ou soit la surface d'échantillon est déplacé vers l'autre.

3. Procédé selon la revendication 2, dans lequel ladite pointe d'essai (12) comprend une protubérance aciculaire sur l'extrémité libre de l'élément en porte à faux (6).

4. Procédé selon la revendication 3, dans lequel ladite protubérance aciculaire est un cristal en forme de trichite d'un matériau sélectionné dans le groupe composé d'un métal, d'oxyde de zinc, d'oxyde d'étain, d'alumine, de carbure de silicium et d'un matériau organique.

5. Procédé selon la revendication 1, comprenant en outre, après l'étape (b), l'étape de commande de la position soit dudit élément en porte à faux (6) ou soit de ladite surface d'échantillon l'une par rapport à l'autre, de telle façon que l'amplitude de la déviation de l'élément en porte à faux (6) devient égale à une valeur constante donnée, durant laquelle les variations de hauteur de la surface d'échantillon sont formées en image sur la base du niveau de commande demandé pour rendre l'amplitude de la déviation de l'élément en porte à faux (6) égale à ladite valeur constante donnée.

Fig.1

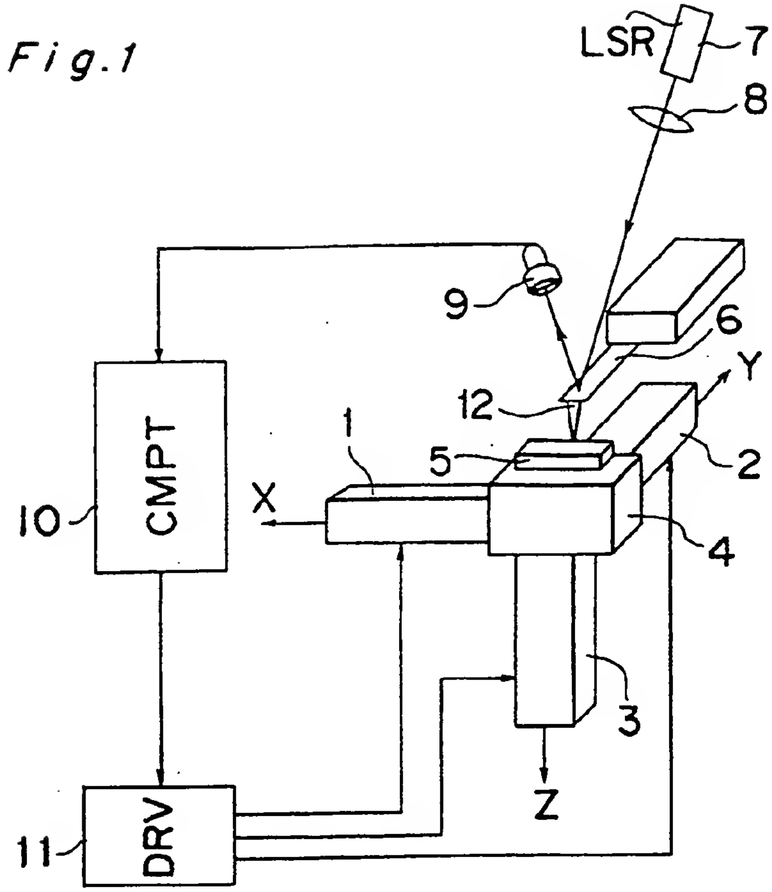

Fig.2

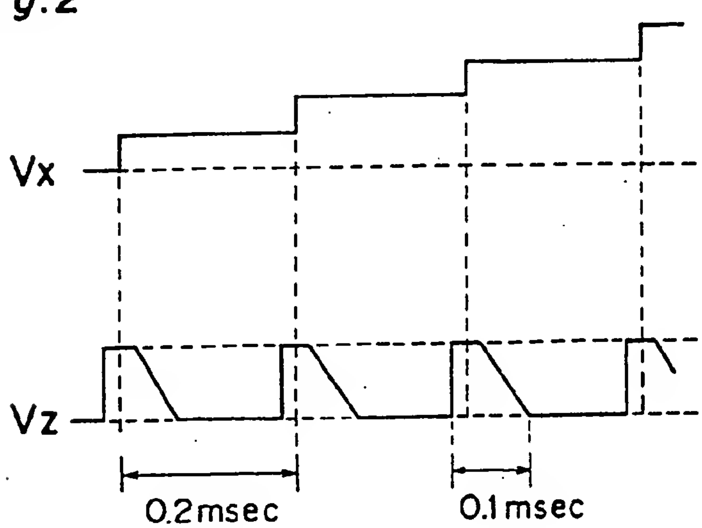

Fig. 3

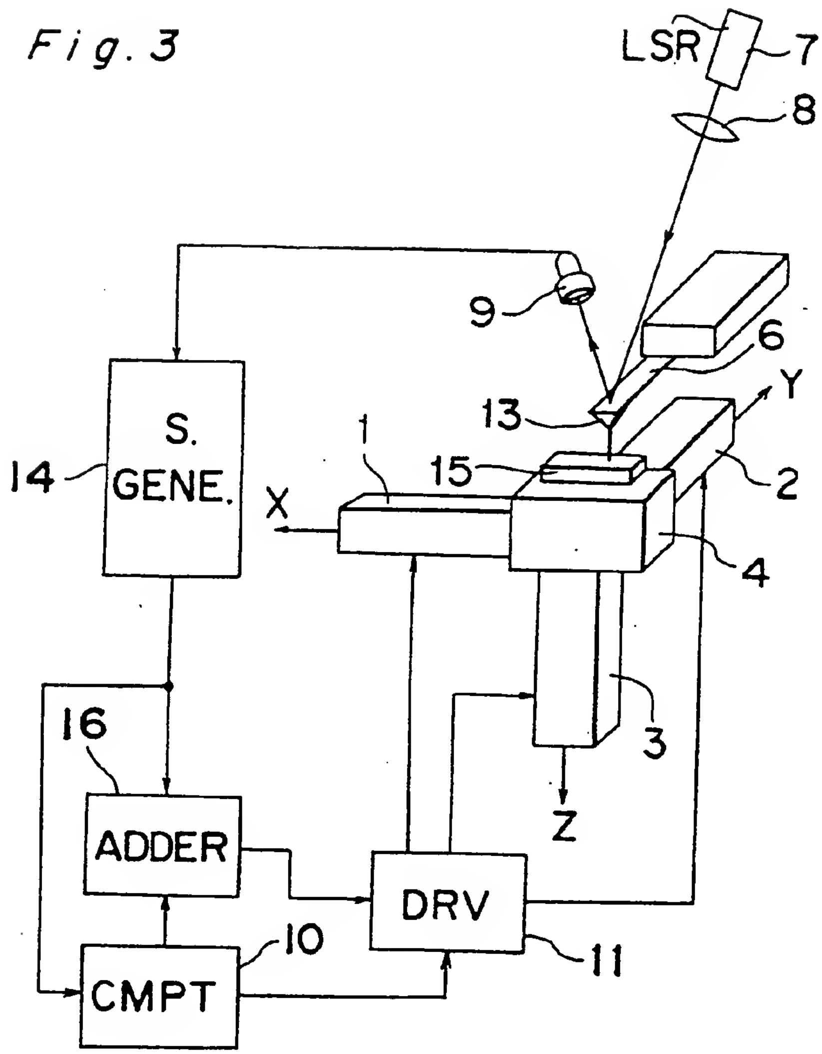

Fig.4

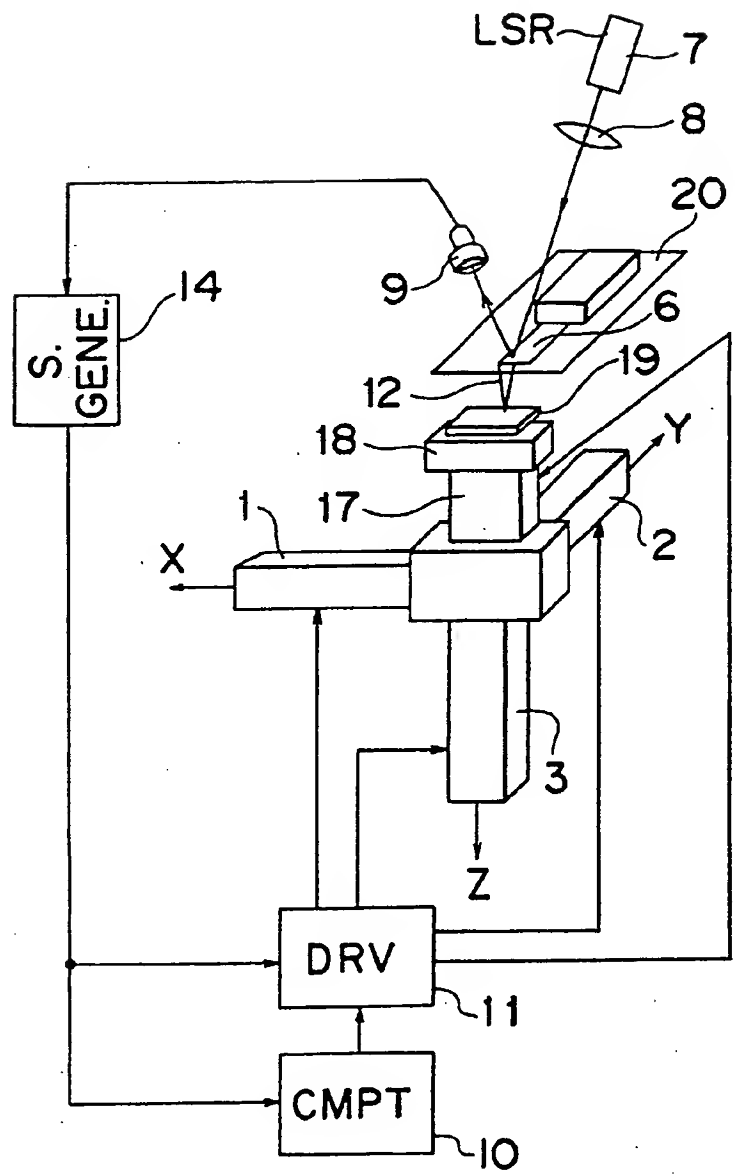

Fig.5 PRIOR ART